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THE EFFECTS OF POLLUTION CONTROL ON THE NONFERROUS METALS INDUSTRIES

LEAD

Part II

Structure of the Industry

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Submitted to
The Council on Environmental Quality
Executive Office of the President
Washington, D.C.

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CHARLES RIVER ASSOCIATES INCORPORATED · CAMBRIDGE, MASSACHUSETTS

December 1971

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THE ECONOMIC EFFECTS OF POLLUTION CONTROLS ON THE NONFERROUS METALS INDUSTRY: LEAD

Prepared for
the Council on Environmental Quality

Prepared by
Charles River Associates Incorporated
16 Garden Street
Cambridge, Massachusetts 02138

December 1971

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PREFACE

This report on the economic effects of pollution controls on the lead industry has been organized into three parts comprised of eight chapters. The three parts can be read separately or in conjunction with one another. Part I summarizes the contents of the succeeding two parts, providing a broad profile of the lead industry and outlining the economic effects of pollution controls on the industry. The important points and conclusions of the full report are contained in the first part, with greater detail and analysis in the following two parts.

Part II comprises separate chapters on:

Trends in supply and the technology of production
Consumption
Structure of the industry
Prices
Government policies
The lead industry in the United States

Part III is our detailed analysis of the economic effects of imposing pollution controls on on the lead industry.

Much of the information contained here was first published in Charles River Associates Incorporated, *An Economic Analysis of the Lead-Zinc Industry* (Cambridge, Mass., 1967, revised 1969), which we prepared under contract with the General Services Administration. Data presented in this report if not otherwise attributed is taken from our GSA report.

PART II

Chapter 2

TRENDS IN SUPPLY AND TECHNOLOGY OF LEAD PRODUCTION

Lead mining and refining are carried out on a worldwide basis, with over 50 countries engaged in these activities in 1968. In mining the shares of different continental areas have remained relatively stable over the past decade, the exception being an increase in the North American share from 35.7 percent to 43.1 percent. This change is due largely to new ore discoveries in the United States (and to a lesser extent Canada); the U.S. share in world lead mine production increased from 12.9 to 21.2 percent over the period.

REGIONAL SHARES IN MINE PRODUCTION OF LEAD IN THE NONCOMMUNIST WORLD

	1960	1970
(United States)	(12.9%)	(21.2%)
North America	35.7	43.1
South America	10.9	9.6
Europe	20.9	18.2
Asia	3.7	3.7
Africa	11.8	7.9
Australia	17.0	17.7

SOURCE: American Bureau of Metal Statistics, *Yearbooks* 1966 and 1970.

The ratio of noncommunist world to total world lead mine production has also remained stable, with the noncommunist world accounting for 74.6 percent and 73.0 percent in 1960 and 1970, respectively.

The world refining picture is similar.

REGIONAL SHARES IN SMELTER PRODUCTION OF LEAD IN THE NONCOMMUNIST WORLD

	1960	1970
(United States)	(20.5%)	(24.5%)
North America	36.3	38.0
South America	5.7	4.1
Europe	34.3	32.4
Asia	4.6	8.0
Africa	5.8	5.0
Australia	11.6	12.0

SOURCE: ABMS *Yearbooks*, 1960 and 1970.

The main lead smelting countries in the noncommunist world, after the United States, are Australia, West Germany, Japan, Canada, Mexico and France. The noncommunist world share of total world lead smelter production matches its share in lead mine production, measuring 74.4 percent and 74.5 percent in 1960 and 1970, respectively.

Although the geographic distribution of ores is widespread, it is uneven. Consequently, there are several countries, generally highly industrialized, which are persistent importers of lead. The major importers are the United States, West Germany, and France. Belgium, Denmark, the Netherlands, Switzerland, and the United Kingdom are almost totally dependent upon

imported metal. Australia, Canada, Mexico, and Peru are the major exporters, although many countries -- generally less industrialized -- have persistent exportable surpluses. Recently Canada and Mexico have expanded their domestic refining capacity to process more of their mine output within their own borders.

Imports enter the United States in either ore or metal form.[1] U.S. refineries imported about 17 percent of their ore in 1970, with Canada, Peru, and Australia being the important sources of these imports. Total imports of ore amounted to about 6.6 percent of the total U.S. lead supply. Imports of metal are substantially more important in this respect, amounting to 14.4 percent of domestic supply. The major suppliers of lead in metal form are Peru, Canada, Mexico, and Australia, who together contributed 84.3 percent of 1968 imports of metal. (See Figure 2-1.)

Lead Ore

Lead occurs in ores which vary considerably in lead content and in content of other recoverable metals such as zinc, copper, and silver. The common lead minerals are galena (lead sulfide), cerussite (lead

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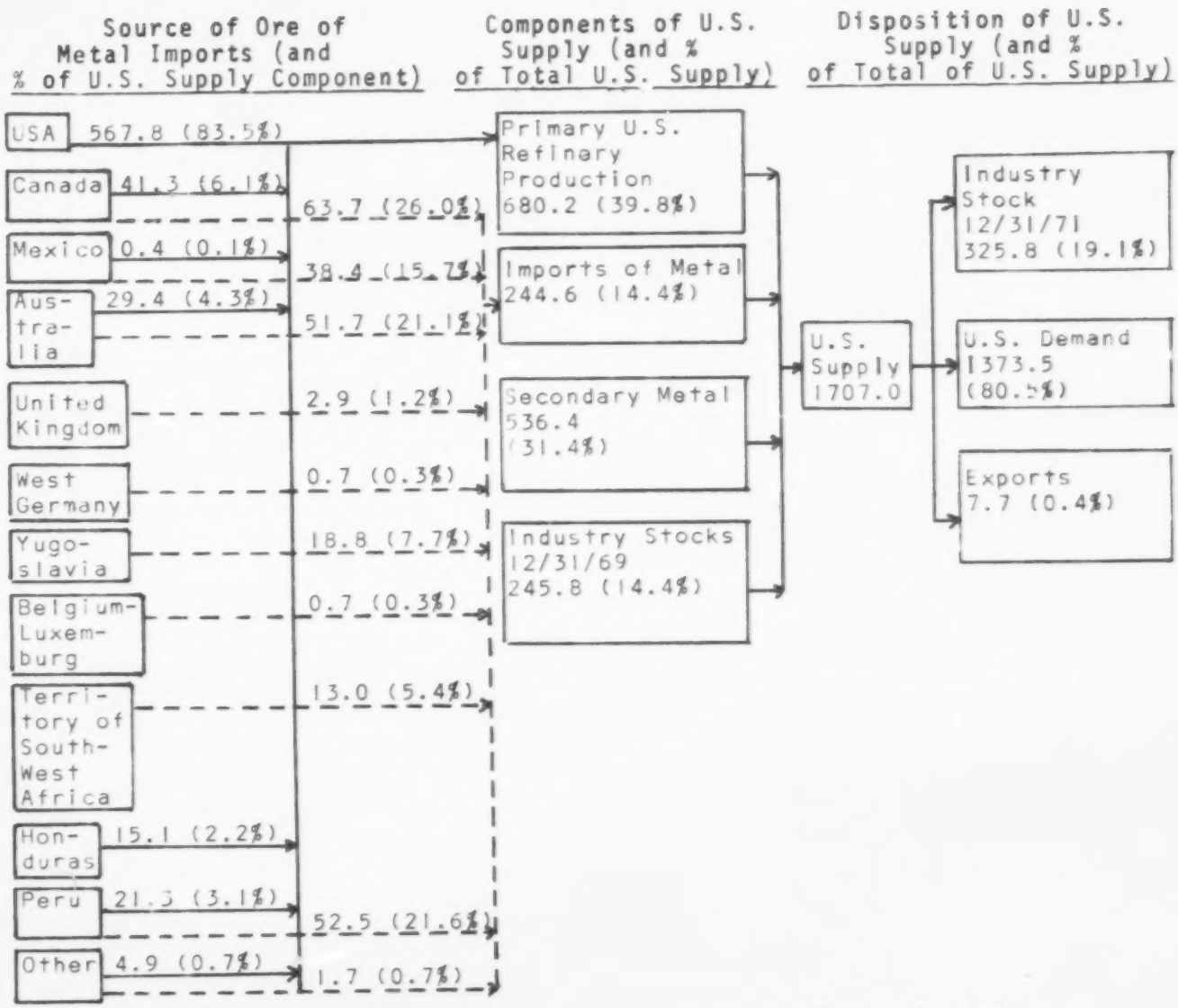
[1]The contribution of imports to total U.S. consumption has fluctuated without marked trend over the past two decades. However, there has been a decline in the ratio of imports to total domestic consumption from 38.7 percent in 1967 to 26.7 percent in 1970, according to figures presented in *Metal Statistics*, 1971 edition. Our own estimate of the share of imported ore and metal in domestic consumption for 1970 is 25.9 percent, as is represented by this chapter's diagram on imports and U.S. lead supply.

Figure 2-1

IMPORTS AND U.S. SUPPLY OF LEAD 1970
(Thousands of Short Tons)


Source of Ore of Metal Imports (and % of U.S. Supply Component)
Components of U.S. Supply (and % of Total U.S. Supply)
Disposition of U.S. Supply (and % of Total of U.S. Supply)
USA 567.8 (83.5%)
Canada 41.3 (6.1%)
63.7 (26.0%)
Mexico 0.4 (0.1%)
38.4 (15.7%)
Aus-tra-lia 29.4 (4.3%)
51.7 (21.1%)
United Kingdom 2.9 (1.2%)
West Germany 0.7 (0.3%)
Yugo-slavia 18.8 (7.7%)
Belgium-Luxem-burg 0.7 (0.3%)
Terri-tory of South-West Africa 13.0 (5.4%)
Hon-duras 15.1 (2.2%)
Peru 21.3 (3.1%)
52.5 (21.6%)
Other 4.9 (0.7%)
1.7 (0.7%)
Primary U.S. Refinary Production 680.2 (39.8%)
Imports of Metal 244.6 (14.4%)
Secondary Metal 536.4 (31.4%)
Industry Stocks 12/31/69 245.8 (14.4%)
U.S. Supply 1707.0
Industry Stock 12/31/71 325.8 (19.1%)
U.S. Demand 1373.5 (80.5%)
Exports 7.7 (0.4%)

SOURCES: *Mineral Industry Surveys*, U.S. Bureau of Mines, January 1970 - December, 1970; ABMS *Yearbook*, 1970, p. 48; U.S. Bureau of Mines, *Minerals Facts and Problems*.

carbonate), and anglesite (lead sulfate). Of these, galena is the most abundant in U.S. lead mineral deposits.

Reserves of Ore

Known ore reserves are dependent upon the state of the economy and relative prices: when demand presses against existing supply, exploration activity is stepped up and additional ore bodies are discovered. Thus world ore reserves estimates are subject to considerable change. In the 1965 edition of the U.S. Bureau of Mines' *Mineral Facts and Problems* world reserves are estimated at 50 million tons, of which 6 million, or 12 percent, were in the United States. In the 1970 edition of *Mineral Facts and Problems*, world reserves were estimated at 95.3 million tons, of which 35.3 million or 37 percent, were in the United States. The change in the U.S. share is attributable mainly to discovery of the new lead deposits in southeast Missouri although deep exploration in the Idaho, Utah and Colorado areas has provided additional reserves.

There are generally four stages in the transformation of lead ore into commercial metal, alloy, or compound: mining, milling, smelting and refining.

Mining

Most of the world's lead ores are extracted from underground mines, but some of the new Missouri supply, as well as some mines in Washington and Peru, is from open-pit or surface mines. In either case the mining process consists in drilling, blasting, and removing broken rock. These processes have become increasingly mechanized

over the past three decades, with resulting gains in efficiency. Improved lighting and ventilation have enabled underground mines with lower grade ores to remain competitive.

Mining Costs

It is possible to characterize mining costs for what can be considered as a representative mine, although the level of costs varies considerably among mines. The typical mining company has large fixed costs, sharply increasing short-run costs, and fairly constant average costs both for moderate output changes in the intermediate term and for substantial output changes in the long run. The intermediate term refers to a period of one to two years in which additional skilled workers and specialized heavy mining equipment can be acquired, and in which new excavations in existing mining areas can be prepared. For shorter periods than this, output increments can be achieved by working the higher grade ore sections of existing mines more intensively, which is costly.[1] Over periods longer than two years, more active exploration and development of new mines can add to mine output; in the past this has occurred without significant increases in unit costs. For decreases in output, the large fixed cost component -- roughly one-third of total intermediate term costs -- imposes sharply rising costs.[2]

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[1]If idle men and equipment are available and unused but prepared excavations, short-run output increments can be obtained at constant cost.

[2]This proportion is based on information contained in *Census of the Mineral Industries* (1963).

Milling

Milling -- the process of separating the mined ore into concentrates of its various metal constituents -- is considered an integral part of the mining operation, and mills are located as near the mining site as feasible. The processes of crushing, floating, and concentrating have changed very little over the past three decades, but automation has increased both efficiency and recovery.

Smelting and Refining

The lead concentrates produced at the mills are smelted to yield metals, alloys, and compounds. The smelting process consists in two stages: roasting and reduction. In the roasting stage, the lead concentrate is oxidized to yield lead oxide in sinter form (this stage is sometimes referred to as sintering) and sulfur dioxide as a gas. The sinter then is reduced either in a blast furnace or an ore hearth, and lead is recovered in matte and bullion form. The blast furnace method of reduction is the most widely used, and the ore hearth method is suitable only for concentrates of high lead content and low impurity. If the concentrate is of sufficient purity, the lead bullion resulting from smelting may need no further treatment. Most lead bullion from blast furnaces also contains one or more of such

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[1] *Mineral Facts and Problems* (1970), p. 614.

[2] Arthur Stern, ed. *Air Pollution*, Vol. III, 2nd edition, 1968.

materials as gold, silver, copper, antimony, arsenic and bismuth. To recover the valuable impurities and eliminate the undesirable ones, bullion is further treated by a series of procedures collectively referred to as refining. As most smelting plants also perform the refining function, the terms "smelting" and "refining" are often used interchangeably.

Pollution Aspects of Lead Smelting and Refining

The major waste emission problems associated with lead production arise in the roasting or sintering stage of the smelting process. Dust and oxide fume of volatile metals are carried off by hot gases. Dust and fume can be recovered by settling in flues and by either precipitation or filtration in baghouses. From 96 to 99.5 percent recovery can be achieved in this way, the higher figures being attainable with baghouses, the lower with precipitators. A more serious problem is presented by the sulfur dioxide emission. Although this gas may be captured, the sulfur content of the lead concentrate is low relative to that found in zinc and copper. Plants for conversion of the sulfur dioxide to sulfuric acid for commercial disposal tend to be smaller and more costly for lead than for the other metals.[1] Other sources of waste emission, such as blast furnace gases and refinery fume, are relatively easily controlled by baghouses and exhaust ventilation systems.

Smelting and Refining Costs

These costs account for about 32 percent of total lead production with 68 percent of the cost attributed to the cost of lead concentrate. Of the costs attributable to the refining process, about 32 to 38 percent may be regarded as fixed in the intermediate term. Thus decreases in output are likely to impose as sharply rising average costs on refineries as on mining operations. Short-run output increases in refining are probably attainable at smaller cost increases than in minings, due to greater ease of adding labor and some equipment. It is also possible to augment fixed plant and equipment more rapidly in refining than in mining, and to do so at a constant unit cost if the plant is large enough to attain economies of scale. It appears that economies of scale are attained with plant sizes ranging from 80,000 to 200,000 tons of pig lead per year. (About three-quarters of the noncommunist world refining capacity is provided by refineries within this range). For smaller plant sizes the long-run unit costs are probably higher.

To summarize, the cost functions of lead smelters and refiners are similar to those of many manufacturing firms: long-run average costs are approximately constant for large-scale operations but rise as the scale of production lowers. Short-run average cost curves are probably U-shaped.

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[1] *Metals Week*, March 29, 1971, reported that Bunker Hill is successfully controlling the sulfur dioxide emissions with acid plants at its zinc smelters, but that it considers its lead smelter acid plant to be uneconomical. The company specified a generally weak demand for acid and cheaper acid entering from Canada as the main problems, but also reported that the zinc smelter acid plants' output was being sold.

Chapter 3
CONSUMPTION OF LEAD

Lead is used predominantly as an input in the production of other commodities. Only a small fraction of lead consumption in the United States can be classified as final goods. The major consumers of lead are the storage battery manufacturers and the petroleum refiners, which together accounted for about 63 percent of domestic consumption in 1970. The remaining intermediate good categories account for about 26 percent. These uses are closely related to construction activity and to the production of durable manufactures. About 7.5 percent can be usefully classified as final goods.[1,2]

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[1] In the available 1970 statistics, about 3 percent of U.S. lead consumption is classified as "estimated unreported consumption."

[2] Figures for both 1969 and 1970 are presented because 1970 may not be a representative year, due to the general decline in economic activity.

DOMESTIC LEAD CONSUMPTION CLASSIFIED BY END USE
1960, 1969, 1970
(In Short Tons and as a Percentage of U.S. Total)

End Use	1960		1969		1970	
Storage Batteries	353,200	(34.59)	582,546	(41.93)	569,741	(42.55)
Petroleum Refineries	163,800	(16.04)	271,128	(19.51)	278,505	(20.80)
Paints and Pigments	100,300	(9.82)	103,969	(7.48)	98,906	(7.39)
Construction	115,200	(11.28)	90,082	(6.48)	67,094	(5.01)
Durable Manufactures	147,800	(14.48)	170,053	(12.24)	132,146	(9.87)
Final Goods	80,400	(7.87)	117,377	(8.45)	100,368	(7.50)
Cable Coverings	60,350	(5.91)	54,203	(3.90)	50,295	(3.76)
Estimated Unreported Consumption					42,000	(3.13)
Total	1,021,050		1,389,358		1,339,100	

SOURCE: *Yearbooks* of the American Bureau of Metal Statistics. (The grouping of ABMS data into end uses is described in the text.)

In most of its intermediate uses, the cost of lead is a small proportion of the total costs of the final products in which it is embodied. The major exceptions to this rule are the lead costs in cable covering, pipes used in construction, some paints, and in final goods.

Consumption of lead has grown slowly over the past three decades in both the United States and the non-communist world. The annual compound rate of growth of

U.S. lead consumption has been less than 1 percent since World War II. Noncommunist world consumption grew at 2.8 percent per year from 1950 to 1960, and at 3.6 percent in the subsequent decade.[1] Technological developments favoring the substitution of other materials for lead have been a major influence on the growth of lead consumption. This influence has served to dampen that growth rate, offsetting to some extent the stimulating effect of a rise in general economic activity over the period. Cable coverings have been a notable example of technological displacement of lead in the past, whereas lead additives in gasoline may be subject to such influence in the future.

It is not possible to represent noncommunist world lead consumption on the same basis as in the table. The data that are available, illustrated by the figure below, do indicate a marked difference between world and U.S. consumption patterns. Whereas cables held a 5 percent share in U.S. lead consumption in 1966, the share in Japan was 15 percent in 1966 (falling to 9 percent in 1970[2]) and in Europe was 25 percent (the 1969 figures for Germany, the United Kingdom, France and Italy were closer to 20 percent[3]). The substitution of

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[1]Figures to 1960 are from our April 1969 report to GSA on the lead industry. Subsequent data are from the 1960 and 1970 *Yearbooks* of the American Bureau of Metal Statistics.

[2]Lead Industries Association, Inc., *The U.S. Lead Industry* (1970).

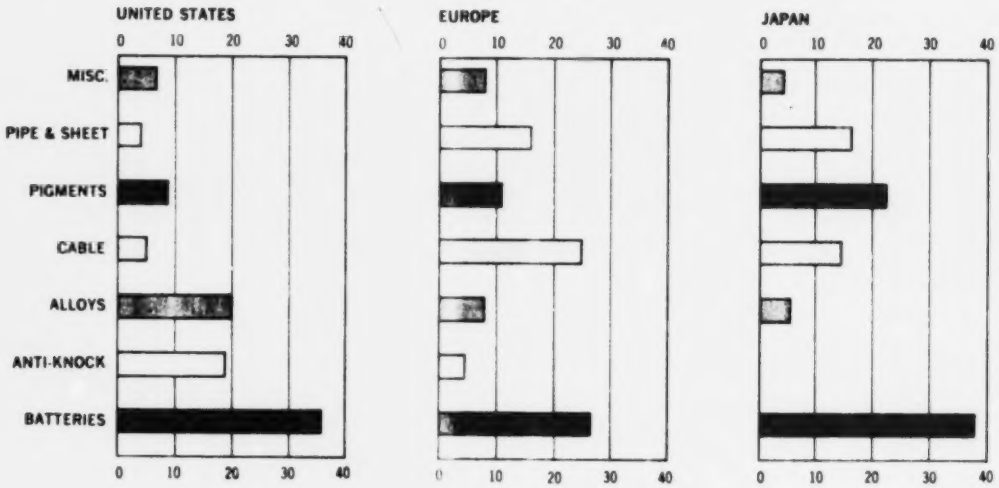
[3]*Metal Statistics* (Frankfurt, 1960-69).

plastics and aluminum for lead as a cable covering is proceeding more gradually abroad than it did in the United States.

LEAD

END USE CONSUMPTION PATTERNS 1966

Per Cent of Total



Reproduced from: Lead Industries Association, *Lead and Zinc: Free World Demand and Supply* (April, 1968) p. 11.

Fewer batteries are replaced in Europe, which explains in part the lower share of battery use there; the corresponding figure for Japan is about 38 percent. (The European battery share remained at about 28 percent in 1969 and the Japanese battery share climbed to about 40 percent in 1970.)

The United Kingdom is the only foreign country consuming significant quantities of lead gasoline additives.[1]

The end use categories listed in the table are useful for analysis of trends in various components of lead consumption. As these trends are influenced by technological development relating to substitute products, a closer examination of these categories is appropriate.

Storage Batteries

Storage batteries have long been the principal end use of lead in the United States and within the past five years have replaced cables as the leading use of lead in the major foreign industrial regions. Lead has long been the predominant material used for battery plates and oxides, enjoying a wide margin of economic superiority over substitute materials. The bulk of lead battery use is in small batteries for starting, lighting and ignition, chiefly in automobiles. Within motor vehicle use, the replacement market is about four times the size of the new product market. Replacement battery consumption is increasing faster than vehicle registration however, reflecting the trend of the past two or three years of increased use in nonhighway vehicles. These include small vehicles, golf carts, snowmobiles, boats, materials handling equipment, and other battery-powered vehicles. Industrial battery use, which now comprises about 10 percent of storage battery use, is

[1]Japan does consume some leaded gasoline, although it is not reported separately by the Lead Industries Association. It is reported in the May 31, 1971 issue of the *Oil and Gas Journal* that legislation is in effect in Japan that will completely remove lead from gasoline by 1974.

growing due to increasing interest in noncombustion vehicles and stationary power systems in hospitals, telephone exchanges, power stations and other installations requiring auxiliary or uninterruptible power sources.

Indispensability of batteries to vehicle starting, lighting, and ignition; the low proportion of lead cost in total battery cost and of battery cost in total vehicle cost; and the wide cost advantage of the lead acid battery over other kinds of batteries have placed lead in a secure position with respect to substitutes.[1] Demand for lead in this major end use continues to be insensitive to price changes of substantial magnitude.[2]

The future demand for lead in batteries providing motive power is less certain; widespread use of electric automobiles could greatly increase the demand for lead. An electric car powered by lead-acid batteries could use up to 100 pounds or more of lead, as compared with about the 30 pounds of lead now used in a standard American car.[3] Such a change in automotive technology could, however, spur advances in battery technology that may favor other materials over lead.

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[1]According to the International Lead-Zinc Study Group, the nearest substitute is the nickel-cadmium battery, which costs about three times as much. See the organization's *Lead and Zinc: Factors Affecting Consumption* (United Nations, New York, November, 1966) p. 20.

[2]See our April 1969 report, pp. 13-19.

[3]*Metals Week*, June 7, 1971, p. 28.

Gasoline Additives

Petroleum refiners use lead in the form of tetraethyl and tetramethyl as gasoline additives to raise the octane level of the gasoline. The higher the octane level, the better the gasoline's antiknock quality.

The price of lead is a small fraction of the cost of tetraethyl, which is used more than tetramethyl, and the lead content of tetraethyl cannot be varied. The price of tetraethyl is a small fraction of the cost of gasoline, but an important part of the cost of refining. Thus a change in the price of lead is unlikely to affect the demand for gasoline, but might affect refinery operations.[1] The main adjustments that can be made at the refinery with existing equipment are to refine the petroleum more highly, which increases the octane level (thus reducing the need for tetraethyl), or to substitute alkylates for tetraethyl. Akylates are considerably more expensive than tetraethyl. Increasing the severity of the refining process can be accomplished by increasing the refinery operating ratio. This also becomes very

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[1]This is not to say that consumers do not consider price in their gasoline purchases. In 1970 when low- or no-lead gasolines were provided by many service stations along with leaded gasoline, leaded gasoline sales reached a record level and sales of unleaded were very slow, in part because of a price differential favoring leaded gasolines. According to *Metals Week* (August 2, 1971) the American Petroleum Institute estimates that about 3 percent of total gasoline sales have gone over to unleaded. In the first four months of 1971, lead consumption in antiknock compounds was 16 percent below the amount for the comparable period in 1970. The API attributes this to a decrease in lead content of leaded gasolines rather than a consumer switch to unleaded gasoline. See our April 1969 report.

costly after an operating ratio of about 90 percent is obtained (the level of the past several years.[1]) Thus lead cost increases which are expected by refiners to be temporary are unlikely to induce a substitution away from lead. A substantial rise in the expected future cost of lead, however, may induce investment in new capacity.[2]

The question of the future of leaded gasolines is the major uncertainty in the lead consumption picture. The question of pollution control devices for automotive emissions has not been settled, as the two main types of proposed devices -- the catalytic converter and the thermal reactor -- have not been fully developed and tested. There seems to be substantial momentum toward the adoption of the catalytic converter, which cannot operate effectively with leaded gasoline. Adoption of the thermal reactor would permit the continued use of lead in gasoline. A reasonable estimate is that the net effects of new cars using lead-free gasoline, reduced lead content of regular grade gasolines, and

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[1] U.S. Department of Commerce, *Survey of Current Business* (July, 1971).

[2] Reports of the construction of new low- and no-lead refining capacity by major oil companies are contained in the February 15 and March 8, 1971 issues of *Oil and Gas Journal* and the September 27, 1971 issue of *Industry Week*. These reports indicate that some expansion plans are being made in anticipation of regulations governing the lead content of gasoline, and that many companies will place new orders once the specifications regulations are made known.

probable regulations in some states will be to reduce the consumption of lead in this segment of the market by about 40 percent by 1975. This will probably reduce the growth rate of lead consumption by almost 1 percent between now and 1975, and by 0.5 percent or less thereafter. In absolute terms, the implied reduction in tons of lead consumed as gasoline additives will be just about offset, if not more than offset, by increased tonnages consumed in storage batteries alone. The prevailing assumption in the trade literature is that from 1975 to 1980, the gasoline additives market will decline by about 10 percent per year, largely as a result of legislation. If 40 percent of that market is lost by 1975, these further declines will probably have no impact on the growth of consumption larger than that discussed above.

Lead Cable Sheathing

The use of lead as a covering or sheathing for power cables declined substantially in the United States in the late 1950's. This decline was associated with the replacement of lead by plastic and aluminum in low voltage cables and by steel and aluminum in high voltage lines. The replacement process is largely complete in the United States, where lead remains the dominant sheathing material only for medium voltage, underground cables. In the recent past, the amount of new cabling placed underground in congested areas has shown no trend. As the placement of cables underground is considerably more expensive than the installation of overhead lines, it may well be that any substantial change in the proportion of total cables placed under ground--both new lines and replacement of overhead with underground cables--will await further cost-reducing technological change. Such change could displace lead even in this use. It appears that

similar considerations apply to foreign use of lead in cables, where this component of the trend in lead consumption has been declining gradually. Whereas before World War II cable sheathing was the major lead application for the world as a whole and before 1965 was the major application in both Europe and Japan, its size and market share have dwindled continuously until it occupies only a small share of the United States and Japanese markets and second place in European markets.[1]

Paints and Pigments

Lead-based paints have wide application in both manufacturing and construction. White lead is used in exterior paints, pottery glazes, and enamels. Red lead paint is a rust preventive prime coat used on structural steel members, automobiles, and other steel products. It is convenient to include terne metal in the discussion of paints as pigments, because its use is also closely related to manufacturing and construction activity. Terne metal is iron or steel plate covered with a lead-tin alloy.

In each case the price of lead is an important part of the coating material used. There has been a decline in lead use in paint in recent years, more marked in the red lead and litharge (PbO) uses and less so in white. The decline results both from reduction of lead content in paint and the development of lead-free paint.

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[1]Lead Industries Association, *Lead and Zinc: Free World Demand and Supply* (1965, 1968).

The influence of price changes in lead usage in paints and pigments appears to take several years to make itself felt, and the magnitude of that influence appears to be small.[1]

Construction

A number of structural or functional uses of lead relates to the construction industry, which consumed about 5 percent of 1970 lead shipments. Slightly less than half of this 5 percent is in the form of caulking for joints in plumbing and drainage systems. The other half is divided roughly evenly between the lead pipes, bends and traps of plumbing systems and lead sheet. New uses for lead sheet are being promoted in sound and vibration control and in roofing materials. A recent *Metals Week* article on the new lead sheet, asphalt paper composite designed to compete with conventional shingles contained an estimate from within the industry that lead use in this category could increase to about 6.5 percent of total annual lead consumption.

The price of lead is a relatively large fraction of the total cost of each device, and may have influenced the patterns of substitution in these materials. It appears that technological change has favored the use of other types of joining and structural materials.

Durable Manufactures and Final Goods

There is a large number of uses of lead in manufactured articles, the single most important of which is

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[1]See our April 1969 report, pp. 25, 197.

solder. A list of other uses, in descending order of importance, would include brass and bronze, bearing metals, weights and ballast, casting metals, lead foil, annealing, galvanizing, chemicals (other than paints and pigments), and lead plating. Because of the wide range of uses within this category, which as a whole accounted for less than 10 percent of 1970 lead consumption, the amounts of annual consumption labelled as "unclassified lead consumption" can be included in this category.

Summary

The price of lead constitutes varying fractions of cost of these numerous uses. It appears that this category is influenced more by general economic activity and the indirect effect of price through technological change, than by the direct effect of a change in the price of lead. The same can be said of the three consumption items classified as final goods: collapsable tubes (such as for tooth paste or hair oil), ammunition and printing type. Within this category, ammunition accounts for nearly 70 percent of final goods activity and collapsable tubes for only 10 percent. This being the case, it is not surprising that changes in the price of lead appear to exert only weak influence on this usage.

Chapter 4

STRUCTURE OF THE LEAD INDUSTRY

To understand the behavior of price and output in the lead industry, it is essential first to know how the industry is organized. The organization of an industry can be approached by focusing on markets where substantial amounts of transactions occur.

Lead is marketed both as a concentrate and as refined pig or alloy form. Roughly half of the world's concentrate production is carried on by integrated firms that own mines, mills, smelters and refineries; this portion is not transacted on the market. For this reason, our discussion of price and output focuses on the market for refined lead.

Primary and Secondary Markets

All refined primary lead products -- refined pig, antimonial lead, and other alloys -- belong in the same market, as pig lead is economically convertible into these other forms. Furthermore, the same firms produce this range of products as part of a single production process.

For some purposes it is important to distinguish between primary and secondary lead products, and a more thorough discussion of this distinction is presented in our April, 1969 report to GSA. Suppliers of secondary products differ from suppliers of primary products with respect to production costs, raw materials sources, entry conditions and concentration. The main cost to secondary producers is the price of scrap lead. Scrap lead is considered new scrap if it is generated during the production of lead, and old scrap if it is reclaimed from discarded lead products. Old scrap accounts for about 85 percent of total scrap supply, and storage batteries account for about 75 percent of old scrap. Other old scrap is provided by obsolete cable covering, pipes, type metal, and sheet, all of which are easily collected, remelted and refined. The lead used in gasoline additives and paints are the major categories of unrecoverable lead, but foil, solder, and collapsible tubes are also unreclaimable.

Entry into the secondary market is easier than into the primary market, as access to secondary raw materials (scrap lead) is much cheaper than access to primary raw materials (mined lead), and the time horizon or entry or capacity adjustment is shorter for the secondary than for the primary sector. It is not surprising then that the secondary lead market is much less concentrated on the supply side than is the primary sector.[1]

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[1] In our 1969 report to GSA, p. 101, evidence was presented showing that in 1963 the eight largest primary firms accounted for all of primary output, while the eight largest secondary firms accounted for 66 percent of secondary output. This relative picture has not changed substantially.

An important difference between the primary and secondary sector is their output composition. Lead is produced mainly as refined pig, in antimonial form, or as some other lead base alloy. Primary producers supply about 75 percent of all domestic refined lead, about 10 percent of domestic antimonial lead, with secondary producers providing the balance. Secondary producers also account for practically all of the remaining lead alloy output. Thus if there were an increase in smelting costs for primary refiners that prompted an increase in their price of lead, secondary producers would have the opportunity to expand their share of domestic refined supply by some small amount in the short run, since their raw materials prices would not be affected immediately. In the longer run this effect would vanish. The share of secondary lead metal in total U.S. consumption has remained around 40 percent over the past decade.[1] In general, however, the supply of lead from the secondary sector is tied to past consumption of lead and is little influenced by the price of lead.

Imports

In addition to the contributions to supply from the primary and secondary producer sectors, imports have been an important source of lead for U.S. consumption. The share of imports in domestic consumption, illustrated in the diagram of the section of this report on production

[1]The shares of primary production, imports and secondary production in U.S. supply are illustrated in the diagram presented in the production chapter of this report.

technology, varied around 20 to 25 percent from 1960 to 1969, and has dropped off to 18 percent in 1970 and about 15 percent from January through July, 1971.[1]

From 1958 to 1965 there were quotes on lead imports, and there remains a tariff on both metal and concentrate imports. Neither the quota nor the tariff appears to have had as large an effect on the share of the market accounted for by imports as did the introduction of low-cost domestic supply from Missouri.

The United States imports both ores and metals. About 20 percent of U.S. ore requirements were imported in 1968 and 1969, which was about the same as the share of imported metal in domestic consumption for those years. Main foreign suppliers of both ores and metals are Canada, Australia, Mexico, and Peru. In each of these countries lead refining capacity is being expanded, which will mean that less ore will be exported. This will strengthen the trend of U.S. refiners to use ores from new Missouri mines.

Prices and Competition

There are two basic prices of lead in the world: the U.S. producers' price and the London Metal Exchange (LME) price. There are other prices which apply to local markets and which sometimes diverge from the LME and New York prices. Large transactions, however, are nearly always made at prices substantially in line with these two major prices, which have been generally parallel over the past two decades. From 1953 through 1957, the New York price

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[1]This recent decrease is attributed to large quantities of new domestic ore and metal production from Missouri beginning in 1969.

was about $0.02 per pound higher than the LME price. This is approximately equal to the U.S. import duty plus insurance and freight at that time. The differential widened during the quota period (1958-1965), but since that time has remained within the tariff and import cost range. Thus the scope of competition appears to be worldwide.

That there are substantial competitive pressures on an international basis does not imply that each nation's industry has a highly competitive structure. In France production is carried on under practically monopolistic conditions. In the U.S. market competitive forces are much stronger, although considerable concentration exists. Furthermore, artificial trade barriers are not negligible. The geographic scope of competition in lead lies somewhere between the two extremes of a national market subject to peripheral import competition, on the one hand, and a cohesive world market where transport costs, imperfectly competitive industry structures, and political barriers are negligible.

Integration and Concentration

In terms of vertical integration, the U.S. lead industry consists of both integrated and nonintegrated producers. Nonintegrated firms include both independent mining firms and custom smelters and refiners. Smelting and refining are commonly performed at the same plant.

The integrated firms own mines and mills as well as smelting and refining plants. The greatest part of their lead output is refined from concentrates produced by their own mines and mills. Custom smelters purchase lead

concentrates from other domestic or foreign integrated or independent companies and either smelt or refine or do both. The custom refiners often refine concentrates for a fee or "toll" without taking title to the material. In other cases they barter refined lead for concentrates, or purchase the concentrates outright.

The distinction between custom refiners and independent producers is not absolute. Some custom refiners own some mining capacity, and integrated firms often do some customer work. Data on industrial organization in many foreign countries is insufficient to make a detailed comparison of the United States with other countries. Treating the rest of the world as a single country, however, it is possible to make some useful statements approximating the overall level of vertical integration of domestic and foreign operations.

Within the United States, refining is more concentrated than mining activity. This difference appears to hold on a world basis as well.[1] Integrated domestic producers account for about 85 percent of total U.S. primary and secondary refined lead, and from 55 to 60 percent of total U.S. output of mined lead. On a noncommunist world basis, the refining capacity of integrated primary producers account for from 70 to 75 percent of world production. The capacity of integrated custom refiners that smelt and refine but do not mine accounts for about 13 percent of world production. In world mining, integrated primary producers account for about 50 percent of mine production, while partially integrated

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[1]This discussion is based upon our 1969 report to GSA on the lead industry and subsequent ABMS *Yearbooks*.

primary producers that mine and smelt account for about 7 percent of mine production.

Secondary lead involves a lesser degree of integration than the primary industry. Scrap collecting is not generally carried out by secondary smelters, who purchase scrap from independent dealers. Fabrication is carried on to some extent by custom refiners, the integrated firms, and secondary smelters. The secondary firms appear to be most heavily involved in fabrication. Lead is also fabricated by firms that are not involved in prior stages of production.

The pattern of market concentration in the lead industry is too diffuse to be called monopolistic, yet too concentrated to be analyzed as perfectly competitive. In such a market, no one firm or small group dominates. Firms usually have difficulty in effecting collusive behavior to yield substantially different long-term price and output patterns from those of a perfectly competitive market. However, such a market is sufficiently concentrated, and potential resistance to price rivalry is sufficiently great, that we cannot expect completely competitive results.

An indicator of the degree of concentration is world concentration in primary lead refinery capacity. In our 1969 report to GSA, we presented evidence indicating that the top four firms' refining capacity accounted for over 40 percent of the total noncommunist world production. The top eight firms accounted for nearly 60 percent, and the top 20 for nearly 90 percent. The domestic concentration level appears to be less than that for the rest of the world considered together. The top four firms accounted for 64 percent of the value of shipments of refined lead, and the top eight firms accounted for about 73 percent.

Looking at some of the larger U.S. lead refining companies, we see both the dominance of the major producers and some indications of domestic trends. St. Joe Minerals Corporation and AMAX-Homestake Lead Tollers, representing the new Missouri production, are rapidly increasing their share of the domestic refined lead market. Bunker Hill, representing the older western (in particular, Idaho) mines, is facing a declining share. ASARCO is chiefly a custom smelter.

Production of Some Large U.S. Lead Refiners
(Percent of Primary & Secondary Lead Refined in the U.S.)

Company	1962	1966	1970
AMAX-Homestake Lead Tollers	--	--	14.6
ASARCO	40.2	38.1	28.6
Bunker Hill	19.0	19.0	15.6
International Smelting & Refining	1.8	2.7	1.5
St. Joe Minerals Corporation	15.6	19.8	26.1
U.S. Smelting Refining & Mining	7.0	6.7	3.8

Source: ABMS *Yearbooks*, 1966 and 1970.

A similar picture emerges from an examination of mining companies. St. Joe is again pictured as a strong and expanding firm, sharing the new Missouri lead with Comineo American, Ozark Lead and Missouri Lead Operating Co., all of which have come into operation since 1966.

Production of Some Large U.S. Lead Miners
(Percent of Total U.S. Lead Mine Production)

Company	1962	1966	1970
St. Joe Minerals Corporation	25.9	40.6	36.7**
ASARCO	3.1	2.2	0.9
Bunker Hill	19.6	10.4	5.5
Eagle Picher	1.7	1.5	0.4
Hecla	10.9	9.3	4.7
Cominco American*	--	--	8.6
Ozark Lead (Subsidiary of Kennecott)*	--	--	7.8
Missouri Lead Operating Co. (Subsidiary of Amax)*	--	--	12.1

Source: ABMS *Yearbook*, 1970 and 1966 for all figures except those marked by an asterisk, which are estimates for new Missouri mine output based on information contained in the following sources: "Lead and the Missouri Boom," *Compressed Air Magazine*, January 1967; U.S. Bureau of Mines *Minerals Yearbook*, 1968 and 1969.

**St Joe's share in 1970 seems to be unrepresentative of that company's growing importance in the industry. Its 1969 share was 47.7 percent, and unusual circumstances appear to have affected its 1970 production performance.

Trends

A preliminary and tentative projection of changes in industry structure focuses on two trends, both of which are attributable in important part to the impact of the introduction of large ore reserves of Missouri, and could be affected by similar but unforeseen occurrences abroad.

It appears that the U.S. industry will become increasingly concentrated, with St. Joe, AMAX, and ASARCO accounting for the major shares. Bunker Hill may face a declining share, while International Smelting and Refining, and U.S. Smelting Refining and Mining will probably continue to dwindle in relative importance. This trend will probably be hastened by any cost increases that are incurred by the industry as a whole.

The second trend is that the U.S. producers will increase their share of the domestic market at the expense of imports, with secondary producers maintaining their existing share. If the import surcharge or an equivalent currency realignment persists, this trend will be somewhat accelerated. Any cost increases incurred by the domestic industry but not by foreign producers is likely to retard this trend.

Chapter 5

PRICES IN THE LEAD INDUSTRY

There are two basic prices of lead. The New York producers' price applies to the United States, while the London Metal Exchange (LME) price applies to the rest of the world.[1] There are other prices that apply to local markets and sometimes deviate from the LME and New York prices, but not for substantial time periods or for large transactions. The price is for common grade lead. (See Table 5-1.)

The difference between the LME and New York prices has generally been within tariff and other import costs, though exceptions to this can be found. The difference widened from 1958 to 1965, at which time a quota on lead imports was in effect. At times it appears that the LME price follows the New York price, but on other occasions the reverse pattern is evident.

In an earlier CRA study the history of lead prices from 1946 to 1969 was examined for evidence of market imperfection and responsiveness of price to changes in market supply and demand, stockpile developments and government policy. A brief summary of that price history

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[1]The volume of lead actually transacted on the London Exchange is relatively small, but most large volume transactions elsewhere are based on the LME price.

Table 5-1

COMPARISON OF LONDON METAL EXCHANGE
AND NEW YORK LEAD PRICES, 1947-1970
(Cents per Pound)

Year	(1) LME[1] Lead Price	(2) New York Lead Price	(2)-(1)
1947	15.27	14.67	-.60
1948	17.16	18.04	88
1949	16.95	15.36	-1.59
1950	13.29	13.30	.01
1951	20.25	17.50	-2.75
1952	16.82	16.47	-.35
1953	11.48	13.49	2.01
1954	12.08	14.05	1.97
1955	13.19	15.14	1.95
1956	14.52	16.10	1.49
1957	12.05	14.66	2.61
1958	9.13	12.11	2.98
1959	8.88	12.21	3.33
1960	9.04	11.95	2.91
1961	8.03	10.87	2.84
1962	7.06	9.63	2.57
1963	7.93	11.14	3.21
1964	12.59	13.62	1.03
1965	14.37	16.00	1.63
1966	11.87	15.12	3.25
1967	10.29	14.00	3.71
1968	10.88	13.21	2.33
1969	13.08	14.90	1.82
1970	13.75	15.62	1.87

[1]Based on monthly average rates of exchange by Federal Reserve Board.

SOURCES: New York Price, *Metal Statistics*.
LME price, *Minerals Yearbook*.
Metals Week, January 11, 1971.

and more recent developments is presented here, together with some interpretive comments.

Price History

The price history of lead is divided into a series of periods. The first period, featuring postwar shortage and rising prices, lasted through the end of 1948; prices rose from the artificially low 1946 ceiling of $0.085 to a high of $0.215 in a series of eight increases. The U.S. increases generally followed foreign price movements.

The second period featured readjustment of prices to weaker demand after the shortage subsided. This period lasted until the Korean War began in mid-1950. The initial weakening of demand reflected a mild winter, the 1948-1949 recession, and inventory reductions. Price reached a low of $0.12 in May 1949 after six reductions and fluctuated throughout 1949. Heavy stockpile purchases and signs of recovering demand accompanied increases, but the latter failed to stick in the face of foreign competition and the failure of the expected recovery in demand to materialize. From July 1949 to May 1950 there were 10 price changes; the price ranged from a high of $0.151 in August 1949 and $0.105 in March 1950.

The Korean War period brought increased prices and various forms of government intervention to moderate U.S. prices, including legal price ceiling and restrictions on use. Foreign lead frequently sold in the United States at a premium over the New York price. The ceiling on the

New York price reached a high of $0.19 in 1951.

The fourth period, from May 1952 to mid-1958, was characterized by moderately depressed, post-Korean War prices. There were major recession-induced breaks in prices in 1953-1954 and 1957-1958. The restoration of active trading on the London Metal Exchange in 1952 brought increased sensitivity of the New York price to foreign and speculative developments. New York prices ranged between $0.11 and $0.16, supported to a signficant extent by U.S. government purchases. Producer dissatisfaction with price was associated with a variety of pressures for government sponsored relief, and expectation of political action received frequent mention in reports of market developments.

The imposition of import quotas launched the fifth period, which covers the duration of quotas from 1958-1965. The price differential between London and New York widened to more than $0.03. U.S. and foreign prices were not, however, rendered independent by the quotas. To the extent that this ore was not committed by long-term contracts, its price depended on the LME price as well as the New York price.

New York prices declined from $0.13 post-quota to $0.095 in 1961 before recovering in 1963. Attempts (sponsored by the U.N.) at industry restraint to alleviate the price decline were unsuccessful. The price had recovered to $0.16 in November 1965 when quotas were removed.

The final period began with the removal of quotas and extends to the present tine. Prices in both New York and London broke in early 1966 and declined into 1968, then increased through 1969. In mid-1970 prices dropped

and continued downward until mid-1971 at which time a levelling pattern seems to have taken hold. In 1966 and 1967, the difference between the New York and London prices appears to have exceeded import cost, but since 1967 it has moved back within that range.

Analysis of Lead Prices

The annual data do not fully reveal the relative frequency of price fluctuations on these markets. The London price changes more often than the New York price, which has remained unchanged for substantial periods of time. Between 1954 and 1960 the longest period of constant price in New York was 18 months. Over the 144 months from 1957 to 1968 the New York price was constant for a total of 101 months. While the price was constant, all producers charged the same price. During periods when the average producer's price was changing, price leads were almost always followed.

The impression conveyed by this history is that the supply and demand structure prevents persistent and substantial deviations from a competitive equilibrium but permits a significant degree of price discipline for periods of a year or more. Although there is no formal producer control nor established price leader, the price has behaved as an administered price upon which the lower cost producers have dominant influence. There have been many periods of greater price stability than can be explained by market forces and government policy alone.

The most recent development in lead prices has been a sharp reduction which began in mid-1970 and has continued into 1971. Since July 1970, when the price stood at about the 1970 average of $0.156, it declined to $0.135 in February 1971, then picked up somewhat. The price stood at just above $0.14 in October 1971. The explanation for this recent price break, which has been paralleled by a similar move in the London price, is the combined effect of substantial increases in capacity and the drastic drop in demand in 1970 and 1971. The increased capacity -- largely from Missouri -- brought large increases in output to the market in 1969 and early 1970. A small part of this additional output was absorbed through a reduction in imports, a large amount by increases in consumers' inventories, and the rest by an increased consumption. The inventory of accumulation tapered off about the same time that aggregate demand dropped in 1970. Producer inventories of refined lead jumped by a factor of nearly three between January 1970 and January 1971. Historically, large inventories in the lead industry have been associated with depressed prices; 1971 has been another manifestation of this association.

Thus current price patterns in the lead industry are dominated by cycical adjustments of inventories, and are not necessarily indicative of an accelerated drop in the price of lead. In our chapter on production we explained that long-run costs are likely to be constant, or perhaps declining, and it is reasonable to expect prices to move again to that level. Over the long term, there has been no market trend in the real price of lead.

NEW YORK PRICE OF LEAD DIVIDED BY
THE WHOLESALE PRICE INDEX, ALL
COMMODITIES (1957-59=100)
(Cents per Pound)

1960	11.86
1961	10.84
1962	9.57
1963	11.10
1964	13.53
1965	15.61
1966	14.27
1967	13.20
1968	12.15
1969	13.18
1970	13.34
1971	11.35

SOURCE: The nominal price was taken from *Metals Week*, and the Wholesale Price Index from the USDC, *Statistical Abstract of the United States*, 1970 and from the USDC, *Survey of Current Business*, September 1971. The figure for 1971 is the monthly average through August.

Chapter 6
GOVERNMENT POLICIES IN THE LEAD INDUSTRY

The U.S. government has been involved at various times in influencing exploration, production, stockpiling, consumption and pricing of lead.

Stockpiling

The lead industry was subject to regulation in World War II and the Korean War, with strategic stockpiling beginning in 1943. Stockpile purchases came mainly from imports; wartime use and later sales disposed of the stockpile. Stockpiling was resumed in 1950 and completed in 1962, when inventories amounted to 1.386 million tons. Disposals for government and commercial use began in 1964, and by September of 1971 the lead inventory stood at 1.129 million tons. The target inventory level is 530,000 tons. In October, 1971, GSA declared that 575,000 tons of lead were in excess of the target.

In October 1971 letters of agreement were signed by all U.S. primary lead producers and GSA. These agreements provided for annual producer purchase from the stockpile of up to 50,000 tons of lead. The purchase period will stretch over about 10 years, with

amounts allocated to individual smelters according to their 1970 production. The allocations are subject to review every three years. The disposal rate may be altered or suspended in times of market surplus, as measured by the ratio of primary smelter stocks to the previous year's domestic primary shipments. The metal will be priced at published quotations with individually negotiated discounts to cover reworking, handling, and distribution costs. Both the GSA and industry officials expect to complete their arrangements in time for Congress to authorize sales in 1972.

Because of the high level of producer stocks of lead relative to shipments, it is possible that stockpile releases will be postponed for 1972. Eventual release is not likely to affect the price of lead, but may reduce the share of imports in domestic supply, as 50,000 tons represents about 20 percent of 1970 lead metal imports.

Tariffs and Surcharge

Tariffs and the current surcharge are also of importance to the lead market. The level of the tariff from 1965 (at which time the quota on lead imports was removed) to August 1971, was $0.0075 per pound on lead ores and $0.010625 per pound on bullion, metal and dross. The statutory rates for these items are $0.015 and $0.02125 per pound, respectively. This statutory rate dates from 1930 and is applicable to products from countries that have not been granted duty preferences or concessions. It is also the rate applicable to all products covered by the August 1971 surcharge if the sum of the pre-August tariff and 10

percent of the invoice value, f.o.b. the foreign port, exceed the statutory rate. Thus the statutory rate is the maximum rate that can apply. If the foreign price is low enough so that the pre-August tariff plus 10 percent of the invoice value is less than the statutory rate, then the tariff actually charged is the pre-August tariff plus 10 percent of invoice value.

As of October 1971, the London Metal Exchange price of lead was about $0.101 to $0.103 per pound. The tariff then applying should then be $0.010625 plus $0.0101 to $0.0103, or $0.020725 to $0.020925 per pound. According to *Metals Week*, October 18, 1971, another $0.01 to $0.0125 is added to the foreign price for freight and delivery charges. All this brings the foreign price into the range of $0.132 to $0.136 per pound, which would represent a substantial discount from the October average domestic producers' price of $0.142 per pound. The foreign price is temporarily depressed by the U.S. East Coast dock strike, which is causing supplies to accumulate abroad. After the dock strike the domestic and foreign price should come back into closer alignment.

It appears that foreign producers of lead are absorbing the surcharge for the short term, lowering their product prices to maintain their share of the U.S. market. This will probably also be the case in the longer run. If foreign producers were to consider the U.S. market unattractive because of the surcharge and were to attempt to redirect their sales to other markets, price in these other markets would tend to decline, eliminating their relative attractiveness.

On balance, however, the effect of a continued surcharge would be to accelerate to some (probably small) extent the trend toward a smaller share of imports in U.S. consumption. (This trend is discussed in this report's chapter on the structure of the lead industry.)

Price Freeze

The price freeze associated with the government's import surcharge is likely to have little effect on the lead industry. The price of lead has been declining since July 1970, although this decline may have bottomed out around the October price of about $0.14 per pound. The Economic Stabilization Act of 1970 -- which empowered the President to implement the freeze -- specifies that prices may not be frozen at levels less than those prevailing on May 25, 1970. The price of lead at that time $0.165 per pound, which would allow the price to rise about 17 percent above its October 1971 level. There was no chance that market conditions would support such an increase within the time limit of the initial 90-day freeze. It is also uncertain whether subsequent government policy will allow the May 25, 1970 level to be attained within the foreseeable future. However, there may be some room for producers to raise price in response to cost increases should they choose to do so in light of market conditions.

Other Policies

The government has participated in lead industry activities in other ways in the past. The Defense Production Act of 1950 (as amended) authorized the government to assist in exploration for lead up to 50

percent of approved costs. The program was extended by Public Law 85-701, enacted in 1958, under the Office of Minerals Exploration until lead was removed from the list of eligible metals in 1962. The program continued in exploration of other base metal deposits, often in association with lead.

Public Law 87-347, enacted in 1961, provided for subsidy payments to eligible small domestic producers of lead and zinc ores and concentrates. Subsidies amounted to 75 percent of the difference between a $0.145 per pound floor and the average monthly New York price. The program was terminated on January 1, 1970. In 1969 payments were $30,860, and over the life of the program about $2.6 million were paid. The recipient mining companies were mostly located in Oklahoma, Utah, and Idaho.

Import quotas on lead and zinc were imposed in October 1958. The quotas were established at 80 percent of the U.S. average annual imports over the 1953 to 1957 period. These quotas resulted from an escape clause investigation under authority of the Trade Agreement Extension Act of 1951, and were removed as a result of a Tariff Commission investigation in October 1965 for ores and November 1965 for metal.

Chapter 7
THE LEAD INDUSTRY IN THE UNITED STATES

The lead industry through the smelting and refining stage of production can usefully be categorized as consisting of a low-cost and a high-cost sector. An important part of the basis for this categorization has to do with the nature and location of ore supplies. For this reason, our discussion of the industry includes these topics.

Ores and Mines

There are three lead mining regions in the United States distinguished by the local type of ore. Ores are classified on the basis of the recoverable metal of major value contained: lead ores, lead-zinc ores, zinc ores, and all other ores from which some lead is obtained.

PERCENT OF DOMESTIC LEAD PRODUCTION OBTAINED FROM ORES BY TYPE, 1968

Ore Type	Percent of Domestic Ore Production
Lead	64%
Lead-Zinc	26
Zinc	4
All Other	6

SOURCE: U.S. Bureau of Mines, *Minerals Facts and Problems*, 1970.

In the eastern states, ores are primarily in the zinc category, with lead being mined as a by-product. Lead ores in the central states are of the lead type, and in the western states lead-zinc and more complicated composite ores predominate. The geographic breakdown of ore reserves and mine production shows clearly the dominance of Missouri in the mining stage of the industry.

ESTIMATED LEAD ORE RESERVES, 1970
(Millions of Short Tons)

States	Reserves
Missouri	31.5
Arizona, Colorado, New Mexico, Utah, South Dakota, Wyoming	1.9
Idaho, Montana, Oregon, Washington	1.6
Alaska, Arkansas, California, Kansas, Nevada, Oklahoma, Texas	0.3

SOURCE: Bureau of Mines, *Minerals Facts and Problems*, 1970.

Of the total estimated ore reserves, 91 percent are accounted for by Missouri, Idaho, Colorado, and Utah. These four states also accounted for 92.6 percent of domestic mine output in 1968, and 96.1 percent in 1970.

U.S. MINE PRODUCTION OF LEAD
(Short Tons and Percent of Total)

State	1968	1970
Colorado	19,778 (5.5%)	20,304 (3.5%)
Idaho	54,790 (15.3%)	59,667 (10.3%)
Missouri	212,611 (59.2%)	432,576 (74.4%)
Utah	45,205 (12.6%)	43,952 (7.6%)
Total U.S.	359,156(100.0%)	578,745(100.0%)

SOURCE: ABMS *Yearbook*, 1970.

There is a definite trend in Missouri's growing importance in the lead mining industry. More than 75 percent of the ore produced from Missouri mines in 1969 came from mines that have been opened since 1960. The physical characteristics of these newly worked deposits permit the use of highly mechanized equipment and automated processes on a large scale, which result in labor efficiencies and metal recoveries substantially above other mining areas. These capital-intensive, low-cost ore removal methods are more important than ore grade in giving the new Missouri mines a cost advantage over the typical mines of Idaho, Utah, Colorado, and elsewhere. The favorable ore position of Missouri is reflected in its increasing share of U.S. lead mine output.

Ores from domestic mines provided domestic refineries with about 83 percentof 1970 requirements -- the remainder being imported. Thus the lead industry is considerably less dependent upon foreign ores than is the zinc industry, which imports about 50 percent of its ores.

Employment and Labor Productivity in Lead Mining

Detailed employment statistics are not available for the domestic lead industry. The Bureau of MInes estimated that about 10,000 production workers were employed in lead and zinc mines and mills in 1968. The 1967-68 edition of the *International Directory of Mining and Mineral Processing Operations*, (published by *Engineering and Mining Journal*) estimates that 18,400 persons were employed in lead-producing mines and mills. This estimate includes workers as establishments listed in that source for which employment figures were not given. The 1970 edition of the *Directory* indicated roughly the same employment figure. Of the total, Utah had 45 percent, Montana 19.7 percent, Missouri 12.1 percent, and Idaho 10.9 percent. The Utah and Montana figures appear to be influenced strongly by copper mining (and to a lesser extent zinc) where lead is a by-product.

The figures presented above emphasize the role of a few major states in U.S. lead mine production, but many more states are sources of small amounts of output. Twenty lead mining states, together with their annual production, are listed in the 1970 ABMS *Yearbook*.

According to the Bureau of Labor Statistics, output per production worker in the primary copper, lead, and zinc sector has increased at the average annual rate of 2.3 percent from 1947 to 1969. The number of production workers declined at a rate of 1.1 percent per year over the same period, but the rate of decline was 0.5 percent over the period 1957 to 1969. A similar profile is presented by indices of total employment in these industries.

Leading Domestic Lead Mining Companies

St. Joe Minerals Corporation is by far the largest domestic producer of lead ore; its lead mines are in Missouri. Cominco American, Ozark Lead Co. (a subsidiary of Kennecott), and the Missouri Lead Operating Company (a subsidiary of AMAX) are the other major lead ore producers whose mines are in Missouri. ASARCO has operations in many states. Bunker Hill has mines in Idaho and Washington; Eagle Picher in Illinois, Kentucky, and Oklahoma; and Hecla in Idaho, Nevada, and Utah.

PRODUCTION OF SOME LARGE U.S. LEAD MINERS
(PERCENT OF TOTAL U.S. LEAD MINE PRODUCTION)

Company	1962	1966	1970
St. Joe Minerals Corporation	25.9	40.6	36.7[1]
ASARCO	3.1	2.2	0.9
Bunker Hill	19.6	10.4	5.5
Eagle Picher	1.7	1.5	0.4
Hecla	10.9	9.3	4.7
Cominco American*	--	--	8.6
Ozark Lead (Subsidiary of Kennecott)*	--	--	7.8
Missouri Lead Operating Company	--	--	12.1

SOURCE: ABMS *Yearbook*, 1970 and 1966 for all figures except those marked by an asterisk, which are estimates for new Missouri mine output based on information contained in the following sources: "Lead and the Missouri Boom," *Compresseed Air Magazine*, January 1967, U.S. Bureau of Mines *Minerals Yearbook*, 1968 and 1969.

[1]St. Joe's share in 1970 seems to be unrepresentative of that company's importance in the industry. Its 1969 share was 47.7 percent, and unusual circumstances appear to have affected its 1970 production performance.

Of the mining companies listed above, it appears that those operating primarily in Missouri are lower cost, for reasons mentioned earlier in this chapter. In the subsequent section of this chapter, the major producers of refined lead whose smelters draw upon these Missouri mines will be characterized as comprising the low cost sector of the industry.

Smelting and Refining

There are essentially four sources of supply of domestic refined lead: primary refineries, secondary refineries, imports, and inventories. In this section we shall discuss the secondary refineries briefly and the primary refineries in more extensive detail.

COMPOSITION AND DISPOSITION OF
U.S. SUPPLY OF LEAD, 1970
(Thousands of Short Tons)

Components of U.S. Supply (and % of Total)	Disposition of U.S. Supply (and % of Total
U.S. Primary Production 680.2 (39.8%)	U.S. Consumption 373.5 (80.5%)
Imports of Metal 244.6 (14.4%)	Industry Stocks 325.8 (19.1%)
Secondary Metal 536.4 (31.4%)	Exports 7.7 (0.4%)
Industry Stocks 245.8 (14.4%)	

Secondary Producers

The production side of the secondary metal market is characterized by relatively easy entry, low concentration, and a cost structure substantially different

from that of primary producers. The scale of operations of a secondary producer is typically very small relative to that of a primary producer. The secondary producers are the chief sources of antimonial lead and practically the exclusive source of other lead alloy output. They produce only about 25 percent of all domestic refined lead. The Bureau of Mines *Minerals Yearbook* noted that nearly 150 plants reported some secondary production in 1969, and the 1970 ABMS *Yearbook* listed 32 companies engaged in secondary smelting and refining. Detailed output data for this sector, which accounted for about 31 percent of 1970 domestic supply, are not available.

Primary Producers

There are six major primary lead refining companies which produce essentially all of domestic primary refined lead. One of these -- U.S. Smelting Refining and Mining Company, whose refinery is the U.S.S. Lead Refinery, Inc., of East Chicago, Indiana -- is engaged only in refining and does no lead smelting. The remaining five companies operate seven primary lead smelters. According to *Mineral Facts and Problems*, all imported ores and concentrates are treated by only two of these companies.

PRODUCTION OF SOME LARGE U.S. LEAD REFINERS
(Percent of Primary & Secondary Lead Refined in the U.S.)

Company	1962	1966	1970
AMAX - Homestake Lead Tollers	--	--	14.6
ASARCO	40.2	38.1	28.6
Bunker Hill	19.0	19.0	15.6

(Table continued on following page)

PRODUCTION OF SOME LARGE U.S. LEAD REFINERS (CONTINUED)

Company	1962	1966	1970
International Smelting & Refining[1]	1.8	2.7	1.5
St. Joe Minerals Corporation	15.6	19.8	26.1
U.S. Smelting Refining & Mining[1]	7.0	6.7	3.8

SOURCE: ABMS *Yearbooks*, 1966 and 1970.

[1]The Anaconda Co., which owns the International Smelting and Refining Co., announced in November 1971 that this smelter will be closed down on December 31, 1971. This will leave 6 primary lead smelters in operation. As the IS&R smelter treated ores owned by the U.S. Smelting Refining and Mining Company and sent its lead bullion to the latter's refinery, the U.S.S.R. and M. refinery may also close down in the near future.

ASARCO

ASARCO has three lead smelters currently in operation. These are located at Glover, Miss., El Paso, Texas, and East Helena, Mont. Each of these facilities is to a considerable extent a custom smelter.[1] A fourth ASARCO smelter, at Selby, California, was closed down in December of 1970. Industry sources indicate that

[1]A custom smelter purchases ores and concentrates from mining companies that do not smelt their own output. Although ASARCO and Bunker Hill own some mines, they are not as vertically integrated as St. Joe or AMAX. The custom smelters purchase heterogeneous concentrates from a variety of mines and prepare them in the proper mix of constituents -- such as lime, iron, and silica -- for smelting. The smelting company may sell the lead bullion on its own or on a commission basis for the mining company. The pricing and marketing agreements between mining and smelting companies are rather complex, but lower concentrate prices generally benefit the smelter and higher concentrate prices tend to benefit the mining company. The distinction between custom and integrated smelting companies is one of degree, as most primary producers purchase some ores from mines other than their own.

two important considerations in the closing of the plant were the old age of the equipment and the loss of foreign concentrate supplies for which the plant was built to other foreign smelters. Rising tax, capital, andlabor costs, as well as expected higher costs for pollution control, are also cited. It should be noted that the latter cost categories were mentioned as affecting all smelters in the industry.

ASARCO's smelter at Blover draws solely on domestic ores, primarily from Missouri. The smelter, which uses an updraft sintering process and has an annual capacity of 90,000 tons of metal, commenced refinery operations in 1968. These facts strongly imply that the Glover smelter is in the category of low cost producers. However, it has no acid plant currently in operation, and may encounter larger pollution control cost increments than other domestic smelters having acid plants. Federal ambient air standards are probably attainable with a tall stack.

The Glover smelter employed 130 people in 1970, according to the Engineering and Mining Journal *Directory*. As of July 1971 there were about 8,200 people, or 0.5 percent of total Missouri employment, engaged in mining activity. In 1970, there were about 3,500 people employed in the primary nonferrous metal industry. The Missouri state unemployment rate in 1970 was 4.6 percent.

The facility at El Paso is a copper and lead smelter with an annual capacity of 420,000 tons charge for lead. The plant employed 975 people in 1970, and produces copper anodes and zinc fume in addition to lead bullion. The bullion is refined at ASARCO's refinery

in Omaha, Nebraska. About half the concentrates smelted at this plant are obtained from foreign sources. Of these foreign sources, ASARCO is sole or part owner of perhaps one-half the properties from which the ore is mined. It appears that the concentrates received at this smelter are from a variety of ore grades, as is typical of a custom smelter. This evidently involves higher costs through thesmelting stage than are the case of smelters which receive more homogeneous material.

ASARCO will install an acid plant at the El Paso smelter, although 90 percent feed sulfur recovery might not be attained. The plant will also employ the closed loop control system to lessen its pollution problems. Such a system involves monitoring the emissions of the plant and adjusting output when ceiling emission levels are approached. If Texas emission standards more stringent than Federal standards are imposed, these steps may not be sufficient. ASARCO is cooperating with Phelps Dodge on a pilot plant for converting sulfur gases into solid elemental sulfur, but its large scale operation of such a system as a significant control device is not expected in the near future. It appears that the El Paso smelter is in the category of high cost producer.

As of July 1971 about 105,500 people, or 2.9 percent of Texas state employment, were engaged in mining activity. In 1960, there were about 9,800 people employed in the primary nonferrous metal industry, and 1,476 of these were located in the El Paso Standard Metropolitan Statistical Area -- a Bureau of Labor

classification. The El Paso area unemployment rate in 1970 was 3.7 percent, which was slightly higher than that for the state as a whole.

The third ASARCO smelter is located in East Helena, Montana. This plant has an annual capacity of 420,000 tons of charge, and employed 210 workers in 1970. The smelter's lead bullion is also sent to the Omaha refinery. About 70 percent of the concentrates smelted at East Helena are obtained from foreign sources and these as well as the domestic ores obtained may be relatively high cost concentrates. Some of the input into this smelter was residue from the Anaconda zinc smelter at Great Falls, Montana. When the Anaconda facility closes down, which it is scheduled to do in mid-1972, this source of input will disappear. ASARCO's East Helena smelter has no acid plant for sulfuric acid production, and faces Montana state pollution control requirements that may be considerably more stringent than are Federal standards. The company is requesting permission to continue operations and to meet environmental standards by means of a taller stack. Industry sources regard this smelter as being one of the higher cost units and the least likely to be able to absorb the extra pollution control costs of a 90 percent feed sulfur removal requirement.

As of July 1971 there were about 4,000 people, representing 2.1 percent of Montana state employment, engaged in mining activity. In 1960, there were 4,765 people employed in the primary nonferrous metals industry. The 1970 Montana state unemployment rate was 5.4 percent.

Bunker Hill

The Bunker Hill facility, which is to some extent a custom smelter, is located at Kellog, Idaho. This plant has been extensively modernized in recent years. According to the annual report of the Gulf Resources and Chemicals Corporation, of which Bunker Hill is a subsidiary, a new updraft sinter machine was installed in 1970 to replace 10 machines that had been in operation for nearly 50 years. There is also an acid plant in operation here, although both the trade press and industry source report this to be a relatively costly acid plant with little or no market for output. Bunker Hill, which owns only a portion of its ore supplies, draws much of its concentrates from the Coeur d'Alene region of Idaho. This region is comprised of relatively labor intensive, high cost mines, several of which have gone out of business over the last decade. According to the 1970 annual report of its parent company, Bunker Hill earned only $1.8 million on sales of $88 million, 69 percent of which was accounted for by lead and zinc. This rate of return on sales of only 2 percent is far below the 13 percent return on lead and zinc enjoyed by St. Joe. All this suggests that Bunker Hill is in the high cost producer category. It has an annual capacity of 390,000 tons of charge, produced 123,000 tons of lead and employed 464 people in 1970. Kellog is not near a large industrial center.

As of July 1971 about 3,600 people, which represents 1.8 percent of Idaho employment, were engaged in mining activity. About 1,000 people were employed in the primary nonferrous metal industry in 1960. The state's unemployment rate was 5.1 percent in 1970.

AMAX

The Missouri Lead Operating Company, which is jointly owned by AMAX and Homestake Mining Company, runs a smelter at Boss, Missouri. This smelter is new, having been opened in 1970. All the concentrates for this smelter are from Missouri ores. A relatively effective acid plant is in operation here, though the company has taken losses on its disposal of sulfuric acid. This smelter is definitely within the low cost category of domestic producers. Its annual capacity is 100,000 tons of lead.

As of July 1971 about 8,200 people, or 0.5 percent of Missouri employment, were engaged in mining; less than half this number was engaged in the primary non-ferrous metal industry in 1960. The 1970 unemployment rate was 4.6 percent.

St. Joe

The country's largest smelter is that of the St. Joe Minerals Corporation at Herculaneum, Missouri. The annual capacity there is 200,000 tons of lead, and a relatively efficient sulfuric acid plant is in operation. Employment in 1970 was 550. All concentrates smelted are from company-owned Missouri ores. The plant is favorably situated with respect to waterway transportation and a sulfuric acid market. St. Joe is definitely in the low cost category, and perhaps the most efficient of domestic lead producers.

Anaconda

The remaining smelter currently in operation is the custom plant of the International Smelting and Refining Company -- a subsidiary of Anaconda -- at Tooele, Utah. The capacity is 300,000 tons charge per year, and employment was 400 in 1970. Concentrates have been obtained from the U.S. Smelting Refining and Mining Company's Utah mines, andbullion has been sent to that company's refinery in East Chicago. No acid plant has been in operation at Tooele. The closing of this facility by the end of 1971 was announced in *American Metal Markets* because of "rising costs over the past five years and a drop in smelter fees".[1]

Smelter Summary

The seven domestic primary lead smelters, soon to be six, can be categorized according to low and high production costs. The dominating factor determining a smelter's placement in the low-cost category is access to low-cost ores. The three Missouri smelters share this advantage as well as that of good waterway transportation. As most Missouri lead is obtainable at roughly the same cost, and as smelter technology does not vary widely among plants (as compared with zinc smelter technology, for example), the chief cost difference among the three low cost producers is probably tne pollution control costs. These are likely to be higher for the ASARCO smelter, which currently has no

[1] *American Metal Market*, November 9, 1971.

sulfuric acid plant, than for the St. Joe and AMAX smelters, which do. The incremental pollution control costs for AMAX and St. Joe, which may be very near to, if not already attaining, the proposed standards, are likely to be much smaller than for ASARCO. It may also be the case that either St. Joe or AMAX has lower sulfuric acid disposal costs (or higher returns), and thus is most favorably situated, but there is no hard evidence for this. Of the remaining high-cost smelters, the El Paso smelter is probably more favorably situated with respect to ore supplies and transportation costs than are the others, and the East Helena smelter is probably least favorably situated in these respects. The Bunker Hill Kellog plant probably has some advantage with respect to pollution control costs, as it already has an acid plant in operation.

Financial Data

To give some indication of the size of the companies in this industry, Tables 7-1 and 7-2 present data on pertinent financial variables of the major lead and zinc producers. The data on sales, income, capital expenditures, and profit rates may be compared with the estimated costs of pollution control presented in the following chapter. It would appear that the estimated capital costs of control facilities for the lead operations of individual firms are small relative to the financial resources available to these firms. However, this is no indication of the impact of such costs on the profitability of these firms. In addition, most

Table 7-1

FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS

(thousands of dollars)

Company	Net Sales	Net Income	Operating Income	Stockholder's Equity	Capital Expenditures
AMAX					
1970	840,720	83,600[1]	115,130	609,700	110,201[2]
1969	753,490	69,090	99,850	553,100	182,710
1968	570,590	59,770[3]	81,370	455,200	101,210
Anaconda					
1970[4]	977,424	63,787	108,845	1,188,375	90,500
1969	1,410,608	99,313[5]	393,128	1,166,172	127,016
1968	1,051,015	88,964	253,465	1,114,800	154,402
Asarco					
1970	717,836	111,718	38,634	676,562[6]	71,719
1969	770,982	100,808	62,361	640,745[6]	25,151
1968	634,081	78,617	39,701	587,120[6]	36,879
Gulf Resources & Chemical (Bunker Hill)					
1970	114,380	5,320	14,535	53,308	3,998[7]
1969	113,684	(8,917)[8]	12,083	49,237	5,453
1968	104,935	5,756	11,726	69,656	9,540
Gulf and Western (New Jersey Zinc)					
1970	1,629,562	44,771	118,112	580,346	86,676
1969	1,563,564	72,050	111,504	590,066	72,825
1968	1,330,565	70,366	147,526	537,874	61,587
St. Joe Minerals					
1970	161,303	26,210	53,097	164,576	15,227
1969	178,974	37,463	36,751	160,038	13,440
1968	150,812	24,973	25,365	135,667	10,304

Footnotes on following page

Table 7-1 (continued)
FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS
(thousands of dollars)

Footnotes:

[1] Includes earnings of RST International - 1970 of $11,500,000.

[2] Excludes $82.7 million cost of additional investment in RST International.

[3] Before net gain of $7,580,000 Re: Salcot Palabora Mining and loss at plant.

[4] Excluded from consolidated subsidiaries in Chile.

[5] After additional Chilean participation in profits of $51,937,000.

[6] Common stockholder's equity.

[7] These figures are net capital expenditures.

[8] Mainly due to Gulf's write-off of Mexican operations at Vera Cruz and provision for losses on discontinued operations in 1969.

Table 7-2

FINANCIAL DATA ON MAJOR LEAD AND ZINC PRODUCERS: PROFIT MEASURES

	Net Income / Net Sales	Operating Income / Net Sales	Net Income / Equity	Operating Income / Equity
AMAX				
1970	9.94%	13.69%	13.71%	18.89%
1969	9.17	13.25	12.49	18.05
1968	10.48	14.26	13.13	17.88
Anaconda (International Smelting and Refining Co.)				
1970	6.53	11.14	5.37	9.16
1969	7.04	27.87	8.52	33.71
1968	8.46	24.12	7.98	22.74
Asarco				
1970	15.56	8.17	16.51	8.67
1969	13.08	8.09	15.73	9.73
1968	12.40	6.26	13.39	6.76
Gulf Resources & Chemical (Bunker Hill)				
1970	4.65	12.71	9.98	27.27
1969	-7.84	10.63	-18.11	24.54
1968	5.48	11.17	8.26	16.83
Gulf & Western (New Jersey Zinc)				
1970	2.75	7.25	7.71	20.35
1969	4.61	7.13	12.21	18.90
1968	5.29	11.09	13.08	27.43
St. Joe Minerals				
1970	16.25	32.92	15.92	32.26
1969	20.93	20.53	23.41	22.96
1968	16.56	16.82	18.41	18.70

Source: Annual Reports of all companies; and Standard and Poor, *Corporate Records*, October and November, 1971.

of the firms in question have substantial operations in other nonferrous metals industries, and will probably have to invest in pollution control equipment in these industries as well.

Analysis of the Cost and Profitability of Lead and Zinc Production in the United States

Our discussion of the domestic primary lead industry has focused on the basis for distinguishing between low- and high-cost smelters. In this section we attempt to estimate those costs. Because of the limited availability of appropriate data, we have not been able to obtain precise estimates of cost or to perform statistical analysis of cost functions. However, there are data available that permit us to estimate the level of costs for the low-cost producers; the results correspond to our impressions obtained from both the trade literature and our conversations with lead industry executives.[1]

The analysis focuses on the St. Joe Minerals Corporation, which is one of the largest domestic producers of lead and zinc, whose operations are largely confined to those metals, and whose annual reports contain more detailed data on the operations of a firm than are available anywhere else. The data is accounting data and does not necessarily reflect causal relations within any given

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[1]See our 1967 report to GSA for further detail on this method of analysis.

year. The data alone are insufficient either to refute or to establish that St. Joe is in the category of low-cost producers or that St. Joe's costs are typical of other firms in that category. For reasons discussed earlier in this chapter, however, we believe that such is very likely to be the case. On the basis of our examination of St. Joe's income statements, we conclude that for normal levels of production, their average costs of production are about $0.082 per pound for lead and about $0.12 for zinc. St. Joe's profits as measured by rate of return on equity appear to be inexcess of what might be considered the marginal rate of return on new equity capital for the economy as a whole and are probably sufficient to attract capital into both lead and zinc production.

Calculation of Costs

The annual reports of the St. Joe Minerals Corporation present data on gross profit for the company, percent of gross profit attributable to each product, revenue from each product, and quantities produced and sold for each product. This information permits the calculation of cost, both total and average, for each metal from the following relation:

Gross Profit = revenue - variable cost

Rearranging this relation and using 1970 annual report data, we obtain the following results:

Variable cost of lead = (price per ton) x (tons sold - tons purchased) - (percent profits due to lead) x (gross profits)

= ($312.38) x (190,759) - (0.67) x ($42,882,079)

= $161.766 per ton or $0.081 per pound.

The comparable figure for 1969 was $143.729 per ton or $0.072 per pound, and for the average of the years 1961-65 was $178.00 per ton or $0.089 per pound.[1] As 1969 was a very good year for the company while 1970 was not, the long run average direct cost under current technology may well lie between $0.072 and $0.081 per pound.

An estimate of average total cost for lead is obtained by allocating overhead, general and administrative expenses, selling expenses and various other fixed costs, and by considering revenues from operations other than primary activities. The calculation performed is to subtract the amount labeled "other income" in the income statement of St. Joe from the figures labeled "administration, selling and research, strike and shutdown expense, mine development and exploration, depletion, depreciation and amortization, and interest". WE call the remainder "net overhead expense".[2] The data from the 1970 annual report yield $14,853,062 - $9,169,661 = $5,633,401. Dividing this total zinc and lead metal production tonnage (tons sold minus tons purchased), which was 413,700 tons in 1970, we get $13.74 per ton or $0.007 per pound, as net overhead cost. Adding this

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[1] In our 1967 report to GSA the issues of by-product revenues, stability of cost schedule in money terms and sales from inventory rather than from current production were examined. The cost estimates presented appear to be reasonable when proper consideration is given to these problems.

[2] An alternate procedure would be to allocate all of the overhead expense to lead and zinc. The result would be an estimate of the overhead expense per pound that exceeds our estimate by $0.01. Use of this higher figure in our analysis below would not lead to any change in our conclusions.

to our estimate of average direct cost, we get $0.081 + $0.007 = $0.088 per pound as the average total cost of lead production in 1970. The results of such calculations for both lead and zinc are summarized in the following table.

	Year	Operating Cost Per Pound	Overhead Cost Per Pound	Total Cost Per Pound
	1961-65 Average	$0.089	$0.009	$0.098
Lead	1969	$0.072	$0.005	$0.077
	1970	$0.081	$0.007	$0.088
	1961-65 Average	$0.090	$0.009	$0.099
Zinc	1969	$0.104	$0.055	$0.109
	1970	$0.125	$0.007	$0.132

If the long-run average cost under current technology lies between the 1969 and 1970 figures, then the data presented above suggest that there has been a substantial decline in real production costs for the low-cost lead producers, and perhaps a moderate increase for low-cost zinc producers. Since 1965 the general price level (as measured by the GNP implicit price deflator for private production) has increased by about 20 percent.[1] If therehad been constant real costs in each industry, nominal costs would have risen by 20 percent to $0.118 in 1970 for lead and $0.119 for zinc.[2]

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[1] *Economic Report of the President*, 1971, p. 201.

[2] The difference between the two industries' actual experience may be due to more rapid increases in zinc concentrate costs for zinc and to the fact that zinc production is more labor intensive than is lead production. Zinc costs have not had the same downward pressure from recent large scale, low cost mine expansions as lead has experienced.

The result of the calculation, then, is that the long-run average costs for lead appear to be within the range of $0.077 to $0.088 per pound. Those for zinc may well be within the range of $0.109 to $0.132 per pound. Because the lower end of these ranges occurred in an unusually profitable year while the upper end of the ranges occurred in a relatively slack year, acceptable average costs estimates might be $0.082 for lead and $0.12 for zinc.

A second useful measure, in addition to our estimate of the lower level of production costs for the lead and zinc industry, is an estimate of the profit in excess of the normal opportunity cost of equity capital for the same group of producers. The calculations for this second estimate are based on less firm ground than are the cost estimates, and the conclusions are more tenuous. The results of the calculation will prove useful, however, in assessing the ability of the low-cost firms to attract new capital into the industry and to absorb exogenous cost increases.

The notion behind this ca-culation is that a given productive activity -- such as primary lead or zinc production -- will need to earn at least a normal competitive profit to continue in business. If the activity can earn a higher rate, it will tend to attract new capital for expansion and if it earns less than this rate it will have difficulty raising capital and will tend to decline. It is difficult to measure this normal competitive rate of return, raking risk and expectations into account, but the idea is powerful enough to warrant an approximation.

The measure adopted is the equity capital cost of production. The calculation uses the data provided by the St. Joe Minerals Corporation annual reports to allocate equity capital to lead and zinc production, to compute the competitive equity cost per ton for each metal, and to see if the difference between price and production costs is sufficient to cover this calculated competitive equity cost of capital. The calculations are illustrated in Table 7-3. At two stages in the calculations, some degree of arbitrary choice is involved: in choosing 7 percent and 10 percent as the competitive return needed to attract new capital into the industry in 1965 and 1969, and in allocating the total equity to lead and zinc roughly on the basis of their apparent long-run contributions to profits. Both choices appear to be reasonable, however.

The point to be made by this calculation is seen in comparing lines 4 and 7 in Table 7-3. There it is seen that the excess of price over average total cost is very large in comparison with the estimated cost of capital for lead. Although the numbers involved may not be entirely accurate, the orders of magnitude appear to be reasonable. The interpretation is that low-cost lead producers, as represented by St. Joe, are earning a rate of return on equity in excess of the return required for these producers to be able to compete with other sectors of the economy for new capital to finance expansion, and that their position in this respect has improved since 1965. In the case of zinc, there is also an excess of the earned over the competitively required rate of return, although it is less than in the case of lead and has diminished slightly since 1965.

Table 7-3
EQUITY CAPITAL COST OF LEAD AND ZINC:
ST. JOE MINERALS CORPORATION
(dollars)

	Company		Lead		Zinc	
	1965	1969	1965	1969	1965	1969
Stockholders' Equity[1]	$116,784,519	$160,037,778	$58,000,000	$80,000,000	$53,000,000	$72,000,000
Cost of Equity at a 7% rate of return[2]			4,060,000		3,710,000	
Cost of Equity at a 10% rate of return[3]				8,000,000		7,200,000
Equity Cost per Ton[4]			$30	$34	$18	$29
Average Price per Ton 1959-69 and 1969[5]			252	298	260	292
1969-70 Average-Total Cost per Ton[6]			136	164	200	240
Excess of Price Over Cost[7]			116	134	60	52

Source: St. Joe Minerals Corporation, *Annual Reports*, (especially 1970).

Footnotes on following page.

Table 7-3 (continued)
EQUITY CAPITAL COST OF LEAD AND ZINC:
ST. JOE MINERALS CORPORATION
(dollars)

Footnotes:

[1]50 percent of total equity is allocated to lead, and 45 percent to zinc. The remaining portion would be accounted for largely by iron.

[2]The equity allocated to each metal is multiplied by the rate of return assumed to be the competitive rate required to attract capital into the industry in 1965 and 1969.

[3]The equity cost was divided by the 1965 and 1969 tonnages of lead and zinc produced. For lead, the 1965 and 1969 tonnages were 133,600 and 233,160. For zinc the tonnages were 202,657 and 243,882.

[4]The 1969 costs of lead and zinc were taken to be $0.082 and $0.12, respectively. As the earlier text pointed out, these costs are within the range observed for 1969 and 1970 and are interpreted as the long-run average cost under current technology. The 1969 figures were deflated back to 1965 by dividing by 1.20. This is the amount by which the implicit GNP price deflator has risen since 1965, as discussed in the text.

[5]This is obtained by subtracting line 6 from line 5.

Summary

The low-cost lead and zinc producers, as represented by the St. Joe Minerals Corporation, appear to be in a strong position. Average real production costs have evidently been declining in lead and rising moderately in zinc. Currently these costs are about $0.082 per pound for lead and $0.12 per pound for zinc. Furthermore, the excess of price over costs appears to be more than adequate for the low-cost producers to bid competitively with the rest of the economy for new capital.

We do not have adequate data for making similar estimates of costs and profits for the high-cost sectors of the lead and zinc industries.

This is one of four reports prepared by
Charles River Associates
for the
Council on Environmental Quality
on: Aluminum
Copper
Lead
Zinc